Evaluation of a LENA-Based Online Intervention for Parents of Young Children

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Abstract

This research investigated the efficacy of a pilot version of an online parent intervention that combined LENA-based automated language environment feedback technology with internet capabilities. Seventy-two parents of typically developing children 9-21 months of age were assigned to immediate- or delayed-treatment (control) conditions. During the treatment phase, parents completed 10 recordings over a 3-month period while engaging in a web-based program supporting interpretation of LENA feedback reports and strategies for increasing talk and interaction. Parents completed additional recordings and language assessments over a 9-month follow up phase. Aggregate analyses found no differences in language behaviors between immediate-treatment vs. delayed-treatment groups. However, parents who started from below average ratings on automated language measures demonstrated significant post-intervention increases which held longitudinally. Importantly, participant children showed significant elevations in language ability. Results suggest that an online intervention approach can help some parents increase talk and interaction in the home. Implications for research and clinical practice are discussed.

Key words**:** language, environment, behavior, parenting, LENA

Evaluation of a LENA-Based Online Intervention for Parents of Young Children

This paper describes the efficacy of an online parenting program designed to provide parents with strategies for enhancing the home language environment of infants and toddlers. The pilot program utilized the LENA (Language ENvironment Analysis) system, which automatically analyzes daylong audio data and generates feedback reports on the number of adult words children are exposed to per day, as well as the number of back-and-forth interactions they engage in with adult caregivers (Xu et al., 2008). LENA's quantitative feedback was coupled with remote coaching and online resources for increasing talk and interaction in the home. The approach was motivated by 1) research demonstrating the importance of the early language environment to cognitive, social and emotional development, 2) the effectiveness of automated feedback for changing parent behavior, and 3) the potential for online programs to reduce intervention costs as well as reach parents across varied learning styles and levels of accessibility and interest.

The importance of the early language environment

Research focusing on adult language exposure and caregiver-child interactions has shown that rich and stimulating language environments can critically impact child language development (Chapman, 2000; Hart & Risley, 1995; Huttenlocher, Haight, Bryk, Seltzer, & Lyons, 1991; Rowe, 2008). Specific properties of adult caregiver language have predicted key metrics of child language development. For example, the frequency with which adults talk to children (Huttenlocher, et al., 1991), the rate at which children vocalize (Hart & Risley, 1995), and the responsiveness of caregivers to child vocalizations (Tamis-LeMonda, Bornstein, & Baumwell, 2001; Topping, Dekhinet, & Zeedyk, 2013) all correlate with child vocabulary size. In contrast, children in language-poor environments may evidence delays in their language development, have lower IQs and demonstrate reduced academic achievement measured longitudinally (Huttenlocher, Vasilyeva, Cymerman, & Levine, 2002; Landry, Smith, Swank, & Miller-Loncar, 2000; Topping, Dekhinet, & Zeedyk, 2011).

The importance of the early language environment to cognitive, emotional and social development and the demonstrated paucity of language input that children from a variety of backgrounds may experience suggest that long term developmental outcomes could be improved more successfully via prevention-focused programs rather than ameliorative efforts applied later in a child's life. Indeed, there is a clear need for programs that inform parents from all social strata of the importance of the home language environment and teach them the skills needed to enhance it to mitigate the negative consequences associated with deprivation in language exposure and social interaction. Then, a crucial component of this type of prevention would be the ability to provide parents with quantitative measures of how much they are talking to and interacting with their children, as such information can serve both to motivate them to incorporate environmental enhancement strategies and also to reinforce their efforts.

Measuring the early language environment

Prior to recent advances in sound capture technology and speech recognition software, informing parents about their child's language environment has been difficult and relied mostly on analysis of short audio- and video-taped interactions and costly professional analyses. Hart and Risley's (1995) seminal longitudinal study of early talk and interaction established the importance of the language environment for cognitive development. However, the logistics associated with early recording technology limited their data collection to hourly recordings sampled once monthly, and it took four years to transcribe and code their 1,200 hours of audio data. Today, quantifying the early language environment of developing children can be accomplished relatively more easily. The LENA system (Xu, et al., 2008), a combination of digital audio capture device (recorder) plus automated analysis software, provides descriptive tools to characterize full-day language environments, including estimates of adult word counts (AWCs) and conversational turns (CTs). The AWC is an estimate of the total number of words spoken by adults near the child wearing the recorder, and CTs indicate the number of vocal exchanges between that child and an adult. The LENA system has increasingly been used in studies to document the language environment of typically developing American children between 2–48 months of age (J Gilkerson & Richards, 2008b) as well as young children in a variety of other populations. For example, the relationship between AWC and child vocalization frequency has been noted in the development of preterm infants (Caskey, Stephens, Tucker, & Vohr, 2011). Moreover, the rates and durational properties of LENA language measures have been shown to be useful in distinguishing the language environments of some clinical populations for whom language-related delays are more common, including children who are hard of hearing (Wiggin, Gabbard, Thompson, Goberis, & Yoshinaga-Itano, 2012), have been diagnosed with an autism spectrum disorder (Dykstra et al., 2012; Oller et al., 2010; Warlaumont et al., 2010; Warren et al., 2010), or are classified as having language delays (Oller, et al., 2010). Further, the system has been used successfully with typically developing children in China, Korea and Saudi Arabia among other countries, offering insight into the language environment of infants and toddlers in different cultures (Aldosari, Almuslanani, Wilson, & Gilkerson, 2012, May; Jin, Seong, Lee, & Pae, 2014; Zhang et al., 2015).

In addition to quantifying and documenting the language environment of infants and toddlers, LENA offers a potential source of performance feedback for adult caregivers that could be utilized as part of a language-focused intervention program. Suskind and colleagues have reported significant elevations in talk and interaction using LENA feedback coupled with caregiver coaching in home visiting programs (Suskind et al., 2016; Suskind et al., 2013). The success of this approach is not limited to the home visiting model, as LENA feedback coupled with group-based instruction on environment enhancement has also been shown to positively influence parent behavior (Zhang, et al., 2015).

The potential for web-based interventions

Though the success of parent-focused programs using environment feedback technology to influence parent behavior and improve child language skills is encouraging, the home visiting model is heavily resource-intensive and is difficult to scale. But while a group setting delivery model is less expensive, it may be inaccessible for parents living in rural locations and others for whom travel is difficult due to physical challenges. Fortunately, rapid advancement in information and telecommunication technology has made it possible to address these issues through web-based intervention programs; see Theodoros (2012) for an overview. The internet is becoming increasingly accessible, with 87% of American adults having internet access according to a Pew Research Center (2014) report. With greater access to information over the internet, the potential for a telepractice model to be deployed in early child development programs and interventions is becoming more realistic. Among the benefits are: greater access to services by rural or disabled populations, cost savings in travel, 24-hour access to information, and greater flexibility for those with rigid work schedules. Further, the utilization of diverse modes of delivery (video, written information, text messaging, etc.) make such a model relatively more adaptable to different learning styles and communication preferences.

Although the use of telepractice is new in the area of early intervention, a growing body of research suggests that it offers a viable alternative to more costly clinical visits. For example, a web-based adaptation of the 10-week Play and Learning Strategies (PALS) intervention demonstrated increases in parent-child interactions post treatment (Baggett et al., 2010), and a web-based adaptation of the Head Start program "Incredible Years" showed high parental achievement toward self-reported goals after completing the program (Taylor et al., 2008), with parents' behavioral change and satisfaction comparable to the original home visiting model. However, despite some advantages for online learning, there are known shortcomings to this approach, including lower completion rates and levels of engagement which somewhat mitigate the benefits in reduced logistics and related scaling costs (Christensen, Horn, & Johnson, 2008).

Limitations aside, increased internet use especially by young parents has changed expectations for service delivery in the early childhood arena (Theodoros, 2012). In an age of rapid data exchange, many parents are accustomed to getting information quickly and expect greater flexibility. For the newer generation of parents for whom technology such as fitness wristbands and smartphones can provide instant feedback and instigate behavioral change, it makes sense to combine technological advances in hardware and software with internet capabilities to explore ways to improve early intervention programs. The benefits of internet-basing with respect to access to service as well as potential cost savings suggest that early intervention providers should consider adding internet options, if proven effective, to their service delivery models.

The current study

The current pilot study explored the efficacy of an internet-based parent training program coupled with quantitative LENA feedback. Our predictions considered results from a study reported by Zhang, et al. (2015) which tested the effectiveness of a similar intervention using LENA feedback and coaching delivered to parents in Shanghai, China, in a group setting. In that study parents with below-average baseline counts were significantly more likely to demonstrate elevations in LENA measures compared to those who began the intervention at above-average levels, suggesting that being rated below average at baseline may be a powerful motivator for parents to effect behavioral changes. Adding a prior finding (J Gilkerson & Richards, 2008b) that most parents reported (often inaccurately) their volubility with their child to be above average, we surmised that receiving feedback that performance was actually below average would both surprise and concern parents, which in turn would have a greater impact than would seeing higher baseline numbers. We thus expected that parents with baseline AWC and/or CT ratings below the 50^{th} percentile (relative to a normative reference set) would be more likely to increase their talk and engagement with their children compared to other parents whose baseline feedback indicated above average performance. This study was designed to test the following research questions:

1. Will parents receiving automated, LENA-based feedback plus online and other support regularly over a 3-month intensive treatment period increase their AWCs and CT counts compared to parents not yet receiving the treatment?
2. Will parents who are below-average on LENA measures at baseline be more likely to show greater gains?
3. Will participants demonstrate behavioral changes that maintain over the 9-month post-treatment period?
4. Will parents attribute changes in their own behavior to the automated feedback reports, compared to other components of the intervention?
5. Will children evidence post-intervention gains on language development assessments and will these changes correlate with changes in parental language behavior?

We hypothesize that parents receiving immediate treatment will show greater gains on LENA measures compared to the control (delayed-treatment) group after the 3-month treatment phase, and that those parents who are below average at baseline will be more motivated to change behavior and will thus demonstrate elevated gains compared to parents who start higher. We also hypothesize that participants will exhibit elevations in language behavior measures longitudinally, and that parents will attribute behavior change to the LENA feedback reports. Finally and most importantly, we hypothesize that children will demonstrate elevations in language skills post-intervention, and that these changes will be correlated with increases in parental language behavior.

Methods

Research Design

This study examined the immediate and residual effects of a 3-month intensive feedback and support pilot program for parents utilizing LENA for in-home audio recording and reports. Families were asked to complete 10 recordings during the intensive treatment period, 8 weekly then 2 biweekly. Afterwards, families continued recording biweekly for three months and then monthly for six months, for a total of 12 recordings during the nine-month follow-up period. Throughout the follow-up period families could access quantitative, LENA-based feedback on their language activity as well as receive additional support and coaching.

Participating families were ordered by child date of birth and alternately assigned one-by-one to immediate- or delayed-treatment groups to ensure age equivalency between groups. The immediate-treatment group started the described program shortly after recruitment. The delayed-treatment (control) group followed a similar course that was offset by three months. During the offset period, these families recorded using LENA on a monthly basis but received no feedback or support. Hereafter, this first 3-month period is referred to as study Stage 1. Study Stage 2 for both groups refers to the treatment period plus subsequent period of follow-up. Figure 1 summarizes the study design overall. In addition to using LENA, all parents completed child language development questionnaires at 3-month intervals over the study course.

INSERT FIGURE 1 ABOUT HERE

Participants

Participant families were recruited via www.babycenter.com, a website providing information about child development and advice for mothers and mothers-to-be. Parents were offered a free, 90-day LENA-based program with a 9-month follow-up period. Participants were required to have a Windows-based computer sufficient to run the LENA software and an internet connection. Parents of children older than 24 months or whose children had diagnosed language delays were excluded, as were those whose native language was not English. A sample of 82 families met all selection criteria; 72 of these families completed Stage 1 (35 immediate-treatment, 37 delayed-treatment) and 49 families completed Stage 2.

Parents provided demographic background information and completed the Developmental Snapshot (J Gilkerson, Richards, Greenwood, & Montgomery, in press), a parent questionnaire assessing expressive and receptive language skills, and the MacArthur-Bates Communicative Development Inventories (MB-CDI; Fenson et al., 2007). Age-standardized scores on both measures were consistent with typical development. Child age averaged 14 months at recruitment. Table 1 provides demographic information across samples. Participating families were not paid for recording but were given $5 gift cards for completing and returning questionnaires ($25 total), and on successfully completing the study families kept the LENA software and other materials.

INSERT TABLE 1 ABOUT HERE

Measures

Child Language Development. Parents completed three child language-focused questionnaires at baseline (just after recruitment) and then at 3-month intervals until study completion. These assessments were: the aforementioned MB-CDI (Fenson, et al., 2007) and Developmental Snapshot (Snapshot; J Gilkerson, et al., in press), and the Child Development Inventory (Ireton, 1992).

For this study, from the MB-CDI we analyzed the Vocabulary Checklist score, an index of child verbal production. The checklist includes 396 items for younger children and 680 items for older children. Cronbach's alpha for the vocabulary score was reported to be $\alpha = .96$ for both infant and toddler forms. Test-retest reliability for parents of 500 children over 6 weeks fell in the $r = .80 - .90$ or higher range, depending on child age.

The Snapshot is a 52-item Yes/No questionnaire that provides a single index of expressive and receptive language skills in children up to 36 months of age. The Snapshot has been shown to have high test-retest reliability ($r = .96$) between monthly total scores, and its development age index was highly correlated with child chronological age ($r = .92$) (J Gilkerson, et al., in press).

The Child Development Inventory is a 300-item questionnaire that assesses a range of development issues in children. Here we included the 50-item Expressive Language subscale which covers multiple forms of communication from simple gestural, vocal, and verbal behavior to more complex language expression. Scores on this subscale were reported to correlate with child age at $r = .83$ for a typically developing sample of 568 children, and Cronbach's alpha for children under 24 months of age ranged from $\alpha = .91 - .94$.

Child Language Environment. LENA software provided the two measures of the home language environments of participating children used in this study, the number of adult words spoken near the children over the course of a day (AWC) and the number of conversational turns engaged in with the children (CT). Briefly, audio data collected with the LENA recorder are processed on a computer using algorithms adapted from speech recognition technology to parse or segment the sound stream by labeled "speakers" or sound categories. For human speech activity, segments can be thought of as an algorithmic analog of utterances and have a minimum duration of 600 ms for child and 1000 ms for adults. Eight categories of human or other sources of sound are identified: male and female adults, the key child (wearing the recorder) and other children, overlapping speech, television/electronic media, ambient noise and silence. Adult segments are fed through an American English-based phone decoder to separate consonant from vowel sounds and achieve a rough syllabification of adult speech, from which word counts (AWCs) are estimated via a previously established regression model. Key child segments are analyzed to identify regions of vocal activity, with one vocalization defined as any child speech-related sound, excluding cries and vegetative sounds, separated by 300 ms of silence or non-speech. Conversational turns are then operationally defined as alternations between speech-related adult and key child segments occurring within five seconds of one another and without any other intervening clear human speech activity. Counts for AWC and CT are generated at the segment level and summed across the recording for the daily total estimates. For the current study we examined both the daily count estimates and age-standardized versions of the same referenced to a large normative sample (J Gilkerson & Richards, 2008a; J. Gilkerson et al., in press).

Intervention

The pilot intervention program included three resource elements: 1) LENA-based feedback reports for parents regarding their home language environments; 2) online educational materials providing information to parents on improving their child's language environment; and 3) ad hoc coaching support by a trained staff member delivered online or by phone. Parents were expected to make use of all three resources over the course of the intensive treatment period; the major components of each resource are described below. A complete list of topics covered in each component can be provided on request by the first author.

LENA reports. Parents were provided a version of the LENA software specifically designed for home use with which they could process, manage and view feedback reports for all in-home audio recordings. Feedback reports (see Figure 2) provided a view of language use over the day as both estimated counts and percentile rankings for LENA measures compared to an age-standardized normative reference sample. Parents could see daily summaries of AWC and CT or review hourly breakdowns of each to learn how their talk and interaction with their children varied throughout the course of a day. Parents were also provided a log booklet to keep track of their activities throughout the day, which allowed them to connect daily activities with their LENA feedback reports.

INSERT FIGURE 2 ABOUT HERE

Program website. The online parent support program provided parents with informational tools about enhancing their child's language environment. Participants were assigned usernames and passwords to access resource materials, which included four main components: webinars, parent forum, talking tips videos, and other educational materials.

Webinars. A total of six live webinars were held during the intensive 3-month treatment period of the intervention. Webinars featured a language development expert (first author) who explained strategies for increasing language activity and answered questions from the group in real time. Each webinar was designed to provide encouragement and support to parents as well as offer information on language-related topics such as the importance of turn taking, using play to motivate interaction, repeating and expanding spontaneous child vocalization, shared book reading and incorporating songs and games into daily routines. Webinar sessions lasted approximately 10 minutes and were offered live several times throughout the day to accommodate varying parent schedules. All webinars were recorded for later viewing by parents who could not attend a live session or for sharing with other caregivers.

Parent discussion forum. Discussion forums provided participants with the opportunity to engage with other parents to share their own experiences at their convenience. Parents were encouraged to discuss various techniques they used to increase language interaction in the home and to share challenges encountered along the way. Each week a question was posted on the forum to promote activity, and parents were encouraged to post their own questions as well.

Talking tips videos. Each week of the 3-month intensive treatment period parents were asked to view a specific "talking tips video" vignette which included examples of parents interacting with infants and toddlers in different settings, using strategies introduced in the webinars and described in the other online materials. For example, a two-minute vignette titled "Slicing and Dicing" depicted a mother making lunch while her toddler "helped" and included examples of talking tips strategies for repeating and expanding on the child's comments, providing encouragement and asking open-ended questions. The weekly questions posted on the parent discussion forums typically asked parents to comment on newly posted talking tips videos, describing the strategies they noticed in the vignettes and commenting on their own experiences with similar approaches.

Didactic materials. Didactic written materials on the website provided instructions and examples of the program talking tips, i.e., tactics and strategies for increasing age-appropriate interactions, as well as a section on shared book reading offering a variety of suggested book lists and guidance for promoting dialogic reading at different stages of development. The website also displayed "hot topics" each week, directing parents to scientific articles illustrating the relationship between early talk and development or any related article that recently may have appeared in the news.

Phone coaching. Coaching support was offered by a trained, fulltime staff member to help parents interpret their reports and to discuss language enrichment strategies and answer parent questions. The coach could be reached by online chat, with questions and responses seen on the screen in real time, or by phone. A minimum of one phone coaching session was required after the first recording, but parents could contact the coach at any point and were encouraged to engage in three monthly phone coaching sessions during the 3-month intensive treatment phase.

Procedure

Immediate-treatment group

Parents received LENA software and a recorder along with website login information during the first week of the treatment period. On recording days, parents activated the recorder when the child first woke up and placed it into the chest pocket of the provided clothing. After 16 hours the recorder would automatically shut off. Completed recordings were transferred to the home computer and processed using the supplied software. After processing, parents could view LENA language measure reports, and summary data from their recording was automatically uploaded to the study coordinators. After the first recording, the LENA coach reached out to parents to schedule a phone meeting to discuss their reports, answer questions and set goals.

Parents were given different assignments each week, such as responding to a parent forum question and/or watching a certain video, and encouraged to take advantage of coaching sessions or to read some of the new journal articles or media reports that were posted to the website on a regular basis. Shortly after recruitment and again at 3-month intervals parents were sent questionnaires to assess the level of their child's current language development.

Delayed-treatment group

During each of the first three months of the study, the delayed-treatment group participants were sent a recorder in the mail. Each time, parents completed one daylong recording, returned the recorder, and received no feedback on recording results. After the 3-month delay, procedures identical to those above were implemented.

Statistical Analyses

We conducted all analyses using SPSS and proceeded in two stages. Our first two research questions were addressed in Stage 1, where we compared language values for the immediate- versus delayed-treatment groups over the first three months (i.e., before the latter group received the treatment). LENA measures for the immediate-treatment group were averaged within family for the second and third months to reduce sampling variance. The delayed-treatment group completed only one recording per month during this first stage. Research question 2 focused on examining the performance of participants whose baseline counts were below the 50th percentile, first during Stage 1 and then in Stage 2. The remaining research questions were addressed in Stage 2 after we combined groups, aligned by treatment onset. Using these data we examined the change in parental and child language values over time during the follow-up period. For these Stage 2 analyses, we averaged post-baseline LENA measures within family for each 3-month block of time again to provide greater measurement stability. To adjust for child age effects on LENA measures, all analyses were conducted on age-standardized measures using normative reference values from J Gilkerson and Richards (2008a); percentiles provided in the feedback reports and here reference that normative dataset. Consistent with a hypothesized differential effect of the program on families with initial low versus high performance, we independently analyzed groups for which initial feedback indicated performance above versus below the 50th percentile (relative to an independent normative reference sample) on AWC and (separately) CT. Finally, we compiled descriptive statistics on parental ratings of the utility of the various components of the intervention. To simplify for attrition effects over the course of the year, results are presented here only for those families who completed each stage of the study. Results are presented using a variety of tests, including repeated measures analysis of variance with contrasts and independent samples *t*-tests and Pearson correlations. Study results are presented here grouped by hypotheses/research questions. Primary results are presented for families who contributed sufficient recording data for each stage of analysis; Table 1 provides additional detail on sample characteristics.

Results

Study Attrition

By the end of the first three months of the study, 17 families (8 from the immediate-treatment group) had chosen to withdraw or did not meet expectations for participation. Seven of these families had provided sufficient data for Stage 1 comparisons, so 72 families (35 immediate-treatment, 37 delayed-treatment) are included in those analyses. Over the succeeding 12 months, an additional 16 families ended participation or did not contribute complete data. Thus second stage analyses, which combines the immediate- and delayed-treatment groups, included 49 families.

A slightly lower percentage of participating families who dropped out during Stage 1 had a college degree compared to those who remained, but this difference was nonsignificant for the same comparison at the end of Stage 2. Otherwise, attrition samples did not differ from the included samples on any of the baseline LENA measures (AWC and CT), demographic factors (gender, education), or on the child attributes we assessed (age, language development).

Stage One: Immediate- versus Delayed-treatment

Stage one results are provided in Table 2. The immediate- vs. delayed-treatment groups did not significantly differ on any demographic or child measures, nor on baseline AWC or CT. Addressing research question 1, no significant increases over time were observed for AWCs or CTs in aggregate analysis of the immediate group. The delayed-treatment group evidenced a decrease from baseline on AWC after randomly starting out marginally higher than the immediate group, $t(70) = 1.65$, $p = .10$. No significant differences were found between groups at months 2 or 3.

Addressing research question 2, analyses of baseline performance subgroups (above or below the 50th percentile compared to a normative reference sample) revealed some distinctions. A 2x2 repeated measures analysis of variance on both AWC and CT revealed no significant treatment x baseline status interaction effects, explainable in part by the relatively small sample sizes and the similar trends observed across treatment groups. However, within the immediate-treatment group, participants whose counts were below average at baseline increased significantly on both AWC and CT during the second month (weeks 5-8), though these advances had weakened somewhat by the end of the third month (week 13). Within the delayed-treatment group, the comparably low at baseline participants did not evidence significant increases in AWC or CT at either the second or third months.

INSERT TABLE 2 ABOUT HERE

Stage Two: Parental Change Over 12 Months

For remaining analyses, the immediate- and delayed-treatment samples were merged as previously described. For the full participant sample, no significant changes in AWC or CT were observed from baseline through 12 months. Figure 3 depicts results for Stage 2 analyses; see Table 1 for additional sample characteristics.

However, continuing on with research question 2, separating families whose standardized language measures indicated above versus below average performance on their baseline recording revealed different patterns for each. Families with higher levels of language activity initially showed no significant change (aside from a slight decreasing trend) over the course of study. But families who started out below average on either AWC or CT demonstrated a significant increase at month 3 (i.e., over the course of the intensive treatment period), and this increase was sustained through month 12 of the follow-up period, addressing research question 3. These low-scoring families also displayed greater improvement over the course of the study compared to the higher-scoring families. Their average change on standardized CT from baseline to month 12 was 11.8 points (SD = 17.1), compared with an average decrease of 7.2 points (SD = 19.9) for the higher-scoring families, $t(47) = 3.59$, $p = .001$. Similarly, on standardized AWC they increased 12.3 points on average (SD = 17.3), versus an average decrease of 4.8 points (SD = 16.3) for the others, $t(47) = 3.42$, $p = .001$. These differences between low- versus higher-scoring families correspond to large effects, Cohen's $d = 1.03$ and 1.02 for CT and AWC respectively. Finally, as illustrated in Figure 3 families who started out below average at baseline had increased on average close to the 50th percentile on AWC and just above it on CT.

INSERT FIGURE 3 ABOUT HERE

Alternately, effects for these families may be reported as change in language environment percentiles. For AWC, these initially low-scoring families increased on average from the 17th percentile to the 43rd by the third month, with an average peak in month 9 at the 48th percentile. For CT, on average families scoring low at baseline increased from the 24th to the 45th percentile by the end of the 3-month treatment period. Their peak performance in month 9 placed them in the 60th percentile.

Stage Two: Impact of Feedback To Parents

To assess the relative impact of different aspects of the intervention program (research question 4), at the end of the treatment phase participants were linked to an online survey asking their perceptions of the degree to which each element influenced their behavior. Fifty-three of the 72 participants who completed Stage 1 (74%) completed the survey. In response to the question “Did any aspect of the program influence you to enhance your child’s language environment?” 45 parents (85%) said “Yes.” We next asked these parents to rate how much they agreed with a series of related statements regarding each component. For example, parents were given the statement “The talking tips videos in the website led me to make behavioral changes that enhanced my child’s language environment” and then rated the extent to which they agreed: strongly agree, agree, not sure, disagree or strongly disagree. Nearly all respondents (93%) agreed or strongly agreed that the LENA reports influenced their behavior. Three quarters endorsed the talking tips video and website components, and over half indicated the coaching and webinar sessions were impactful. Only 28% of respondents agreed the parent forum contributed to behavioral change. Parents also rank ordered the program components with respect to which was the most influential for their own behavioral changes. Seventy-one percent chose LENA Reports, 13% chose the talking tips videos, 9% chose the coaching sessions, 4%

chose the webinars, 2% chose the didactic written information on the website, and no parents ranked the discussion forum as the most important component.

Stage Two: Child Language Change Over 12 Months

To address research question 5, child language measures were examined for Stage 2 participants with complete data from baseline to month 12 separately for each measure. Summary descriptive statistics and analysis results are provided in Table 3, including groupings for participant families below and above the 50th percentile for CT at baseline. Little change was observed for the MB-CDI standardized vocabulary score, while the expressive language development quotient from the Child Development Inventory and the Snapshot showed an increase from baseline for the aggregate sample and for families whose CT scores at baseline were above average.

INSERT TABLE 3 ABOUT HERE

We also examined consistency among the child language development measures via paired correlations for the 44 families assessed at month 12. The strongest relationship was observed between the MB-CDI vocal production score and the Snapshot score, $r(42) = .77$, $p < .001$, $R^2 = .59$. The Child Development Inventory expressive communication score correlated similarly with scores from the MB-CDI, $r(42) = .72$, $R^2 = .51$, and the Snapshot, $r(42) = .68$, $R^2 = .46$, both $p < .001$.

Complete Snapshot data were available for 44/49 (90%) of the Stage 2 sample. Change in child language development scores from baseline to month 12 correlated in the positive direction with change in age-standardized CT scores, $r(42) = .37$, $p = .01$, $R^2 = .14$, as to a lesser extent did change in AWC, $r(42) = .29$, $p = .06$, $R^2 = .08$. This relationship was more pronounced in the low-scoring families both for CT, $r(21) = .49$, $p = .02$, $R^2 = .24$, and for AWC, $r(13) = .45$, $p = .09$, $R^2 = .20$.

Discussion

The current research investigated the efficacy of an online pilot program designed to help parents increase talk and interaction in the homes of infants and toddlers. Parents were provided with feedback reports generated from automated analysis of daylong language environment data coupled with access to online resources and phone based coaching. It was expected that parents would demonstrate measurable changes in their child's language environment, which in turn were hypothesized to positively influence child language development over time. Although the results presented here are early stage analyses of an initial design for a pilot program, they suggest that the online intervention program as implemented effectively met this goal for at least a subset of participating families.

The effects of the program were evaluated in terms of five research questions. First, we asked whether parents who participated in the 3-month treatment demonstrated elevations in talk and interaction compared to a control (delayed-treatment) group. Comparing AWC and CT before and after the 3-month treatment phase (Table 2), the data suggest that as a group, parents receiving the treatment did not significantly change their language behavior over this period and did not differ on talk and interaction in the home compared to the parents in the control group.

The absence of immediately apparent overall effects during the key control period leads to our second question: were parents at below average levels on baseline LENA measures more likely to make greater increases in AWCs and CTs? As shown in Table 2, the lower performing group of parents in the immediate-treatment condition did increase their AWC and CT significantly over this period, at least initially, and the higher group dropped to some degree from their initial scores. Conversely, the control group who started below the 50th percentile did not evidence significant elevations in adult talk or interaction. The increases observed for the immediate-treatment group who started low compared to the low-starting control group suggest that parents who receive feedback that their scores are below average may be more motivated to change behavior, and that the intensive treatment phase of the intervention was impactful to this end. Such results are encouraging if we consider that this is the target group for interventions designed to enhance the early language environment.

Our third research question extended the second to ask whether participants would demonstrate gains longitudinally over the 9-month follow-up phase after the families began the intervention. The comparisons in Figure 3 between baseline vs. later scores indicate modest, non-significant change for the overall sample that showed evidence of returning to baseline by Month 12. However, markedly different treatment effects were present between participants who started below versus above average on language environment measures. Parents who were below the 50th percentile on AWC showed a 39% increase in AWC after the 3-month treatment, and parents whose initial CT scores were below average increased turns by 54% post treatment. Further, the immediate elevations for the initially-low group held over time – nine months after treatment, their exhibited adult word counts remained on a par with their performance immediately after treatment. Interestingly, CTs for the low performing group were even higher at longitudinal follow-up, increasing from the 45th percentile immediately after treatment to the 53rd percentile nine months later. We attribute this sustained increase at follow up to a strong emphasis on the importance of adult-child interactions throughout the program, as well as the cumulative effects of increased engagement over time.

The fourth research question investigated participant perception of the extent to which various components of the intervention influenced behavior. Seventy-one percent of parents judged the automated feedback to be the most impactful. Interestingly, while the talking tips videos were ranked higher than the coaching sessions, webinars and didactic written information, all were rated as most influential by at least one participant. More research is needed to determine how each component can be used most effectively to influence different subsets and address a variety of learning styles and preferences.

Conclusions regarding the online intervention aspect of this research are mixed. The attrition rate was high, with 17 participants discontinuing participation during the 3-month treatment phase (21%) and an additional 16 dropping out over the 9-month follow-up phase (40% combined attrition). Attrition was not found to be related to differences in baseline performance, or child age or language scores, and the recruitment sample overall was relatively homogenous with respect to socioeconomic status. Although we were unable to pinpoint a direct causal factor, these statistics are generally consistent with those for other online adult learning programs and may be in part a consequence of the lack of in-person human interaction associated with online learning approaches.

Our final research question speculated that parental efforts to increase talk would lead to measurable improvement in child language outcomes over time. As a group, children whose parents completed the program seemed to benefit to some degree from their involvement, as age-standardized scores increased significantly from baseline on two of the three language ability measures. Specifically looking at the relationship between changes in parent behavior and child language development, we found that parental effort to engage more with their infants and toddlers (quantified through the CT proxy) correlated moderately but significantly with increases in child language ability on the Developmental Snapshot. For the families below average at baseline, changes in turn-taking behavior accounted for nearly one quarter of the variance observed for Snapshot estimates of child language skills. This result is consistent with research pointing to the importance of conversational turn taking for language development (Zimmerman et al., 2009) and importantly emphasizes the potential impact of interventions focusing on increasing parent-child interactions on child language development.

Broadly, the findings presented here can inform research and clinical practice in a number of ways. First, this research suggests that interventions focused on enhancing the early language environment could utilize baseline information as a type of screening tool to determine which parents would be good program candidates, as parents who start out lower are likely to be more responsive to (and in need of) the intervention. Expanding on this idea, results suggest that this technology may be conducive to a response to intervention (RTI) or multi-tiered structure of support (MTSS) approach, which is a framework focusing on providing a flexible system of support for learners with varying levels of skills (Greenwood et al., 2012). More specifically, initial recording results could be used to determine which families may need a higher level of instruction and support (e.g., one-on-one/home visiting) versus a parent group model or something lower touch like online instruction or simply monitoring at intervals. On the whole, the current study suggests that online interventions offer an effective means to provide parents with the tools necessary to increase talk and interaction in the home and underscores the importance of conducting longer term follow up with respect to both parental behaviors and child outcomes. Results also suggest that it is important to take steps to obtain a representative and stable language environment estimate before beginning intervention, such as by completing and averaging together multiple recordings at baseline.

The early-stage nature of the approach undertaken presents several challenges to both internal and external validity, and there are additional limitations associated with this study that could be ameliorated in future research. Although the overall sample size was considered adequate to address our primary hypotheses, the resulting sample of interest (i.e., families with low language use environments) was smaller than intended. Additionally, since the sample included mostly middle-class, college-educated parents, it is unclear to what extent caregiver performance results would generalize to other socioeconomic groups. A notable risk to internal validity is associated with participants' awareness of the overall goals of the intervention. More specifically, the delayed-treatment (control) condition was implemented to provide a direct assessment of the immediate impact of the intervention, but parents in this condition knew enough about the study possibly to have modified their behaviour before treatment began. Additionally, the analyses presented here relied heavily on comparisons to a single first recording, as compared to other studies that have used an average of three to establish a baseline, and thus was more susceptible to unpredictable confounding effects. Studies incorporating these or other sorts of automated, recording-based measures should be conducted with consideration toward reducing these types of validity threats.

Future research could build on the results reported here in a number of ways. From a research perspective, although results suggest that families who start below the 50th percentile benefited more from the intervention, the choice to split parent groups at the 50th percentile was motivated by previous research showing that parents who began a similar program below average on LENA measures showed more substantial increases in AWC/CT compared to other parents (Zhang, 2015). However, it is not clear that the 50th percentile is the optimal cut point at which change is more likely, and it is perhaps an oversimplification to consider only two groups.

More research is needed to determine how baseline recordings can be used to help clinicians identify families most likely to benefit from similar interventions. From a clinical perspective, it would be interesting to develop and test a multi-tiered system of support intervention approach that could use baseline (or multiple baseline) LENA measures to inform assignment into different types of interventions, so that limited resources could be targeted for maximum effectiveness. Finally, although the results presented here suggest that a remote learning style intervention using automated feedback to caregivers can effectively influence parental behaviors and child outcomes, more work is needed to determine which populations can benefit maximally from this modality compared to home visiting or parent group intervention approaches.

Conclusions

This study tested the efficacy and viability of a pilot online intervention designed to provide parents of infants and toddlers with information about the importance of the early language environment as well as strategies for increasing talk and interaction in the home. The results presented here suggest this type of intervention can positively impact the language behaviors of parents whose talk and interaction are initially low. Importantly, an effort to engage more with children can have a significant impact on long term development, as evidenced by the correlation between elevations in conversational turn taking and child language ability at 12-month follow up. Although more research is needed to determine how this modality can be used most effectively with different demographic subsets, the research presented here suggests that a web-based program coupled with environmental language feedback may be a viable approach for helping parents enhance the home language environment of infants and toddlers.

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Table 1

Demographics and Language Scores Across Intervention and Analysis Samples

	Recruitment		Stage 1				Stage 2	
	Full		Immediate Tx		Delayed Tx		Full	
	N	%	N	%	N	%	N	%
Overall Sample	82	100%	35	49%	37	51%	49	100%
Female Sample	34	41%	12	34%	16	43%	20	41%
Mother's Education								
High School/GED	7	9%	2	6%	3	8%	3	6%
Some College	5	6%	6	17%	0	0%	3	6%
BA or higher	70	85%	27	77%	34	92%	43	88%
Included Recordings	1366	93%	355	88%	111	97%	897	95%
	M	(SD)	M	(SD)	M	(SD)	M	(SD)
Child Age (mo)	14.1	(3.3)	13.9	(3.3)	13.8	(3.2)	13.9	(3.1)
Developmental Snapshot	98.9	(12.9)	98.4	(13.6)	100.3	(11.8)	98.4	(13.3)
MB-CDI Verbal	98.3	(12.2)	98.3	(12.1)	99.3	(12.2)	97.7	(12.6)

Note: MB-CDI = MacArthur-Bates verbal standard score.

Table 2

Stage 1: Change in AWC and CT over 3 Months For Immediate vs. Delayed Treatment

	Standardized AWC[a]				Standardized CT[a]			
Group/Time	N	Mean	(SD)	P[b]	N	Mean	(SD)	P[b]
Delayed Tx								
Baseline	37	111.62	(19.56)		37	105.74	(13.20)	
Weeks 5-8	37	102.08	(15.97)	.007	37	103.02	(11.96)	.16
Weeks 9-13	37	101.52	(19.61)	.01	37	100.73	(17.26)	.09
Immediate Tx								
Baseline	35	104.15	(18.82)		35	102.74	(16.73)	
Weeks 5-8	35	102.07	(20.41)	.54	35	102.72	(17.29)	.99
Weeks 9-13	35	104.24	(15.63)	.97	35	102.07	(16.42)	.77
Immediate Tx < 50[c]								
Baseline	13	84.09	(7.68)		17	89.14	(8.86)	
Weeks 5-8	13	89.70	(5.75)	.01	17	95.99	(10.79)	.003
Weeks 9-13	13	91.34	(11.61)	.09	17	93.93	(14.38)	.18
Immediate Tx ≥ 50[c]								
Baseline	22	116.01	(11.97)		18	115.58	(11.23)	
Weeks 5-8	22	109.39	(22.46)	.20	18	109.07	(20.00)	.09
Weeks 9-13	22	111.87	(12.43)	.20	18	109.76	(14.68)	.03

[a]Language measures standardized by child age (M = 100, SD = 15). [b]*P*-values denote contrasts between Baseline and other time points. [c]Sample with language measure performance below versus at or above the 50th percentile at baseline.

Table 3

Stage 2: Change in Child Language Measures over 12 Months by Baseline Performance Group

	Developmental Snapshot SS				MB-CDI Vocab SS				Child Dev. Inventory Expressive DQ			
	N	M	(SD)	P[a]	N	M	(SD)	P[a]	N	M	(SD)	P[a]
Combined												
Baseline	44	100.4	(14.3)		42	98.5	(11.0)		25	107.6	(19.5)	
Month 3	44	107.6	(15.4)	.001	42	98.7	(14.5)	.91	25	113.7	(18.2)	.02
Month 12	44	106.7	(16.4)	.01	42	101.7	(16.9)	.11	25	135.4	(43.7)	.001
Below 50%												
Baseline	23	95.0	(15.0)		21	94.1	(8.4)		12	104.0	(25.4)	
Month 3	23	101.5	(16.5)	.02	21	92.5	(13.3)	.58	12	109.0	(21.6)	.22
Month 12	23	100.6	(18.8)	.18	21	94.9	(15.1)	.77	12	127.3	(47.0)	.04
Above 50%												
Baseline	21	106.3	(11.0)		21	103.0	(11.7)		13	111.0	(11.8)	
Month 3	21	114.4	(10.8)	.002	21	104.9	(13.1)	.38	13	118.0	(14.0)	.04
Month 12	21	113.5	(10.1)	.01	21	108.4	(16.3)	.04	13	142.8	(40.9)	.008

Note: Performance grouping was based on CT performance at baseline. MB-CDI = MacArthur-Bates verbal standard score.
[a]*P*-values denote contrasts between Baseline and other time points.

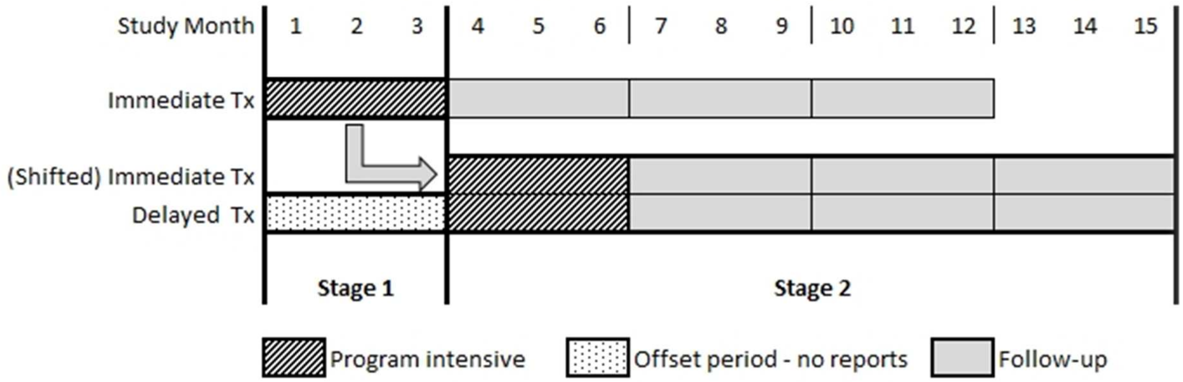

Figure 1. Study design analysis stages

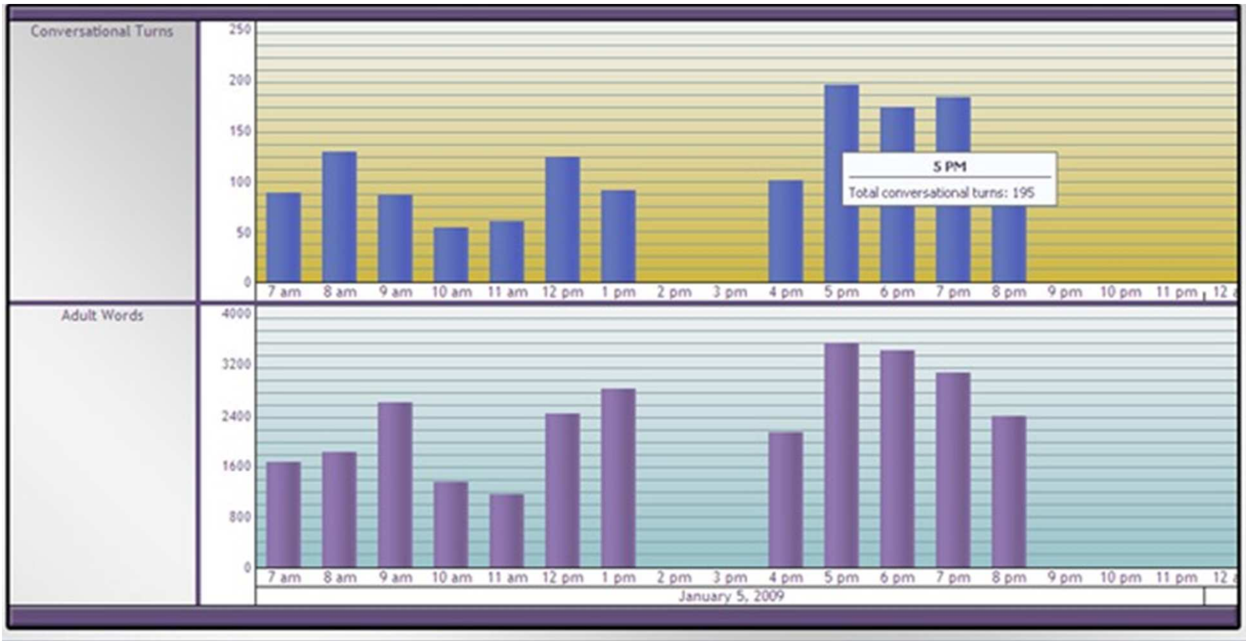

Figure 2. Sample hourly LENA feedback report

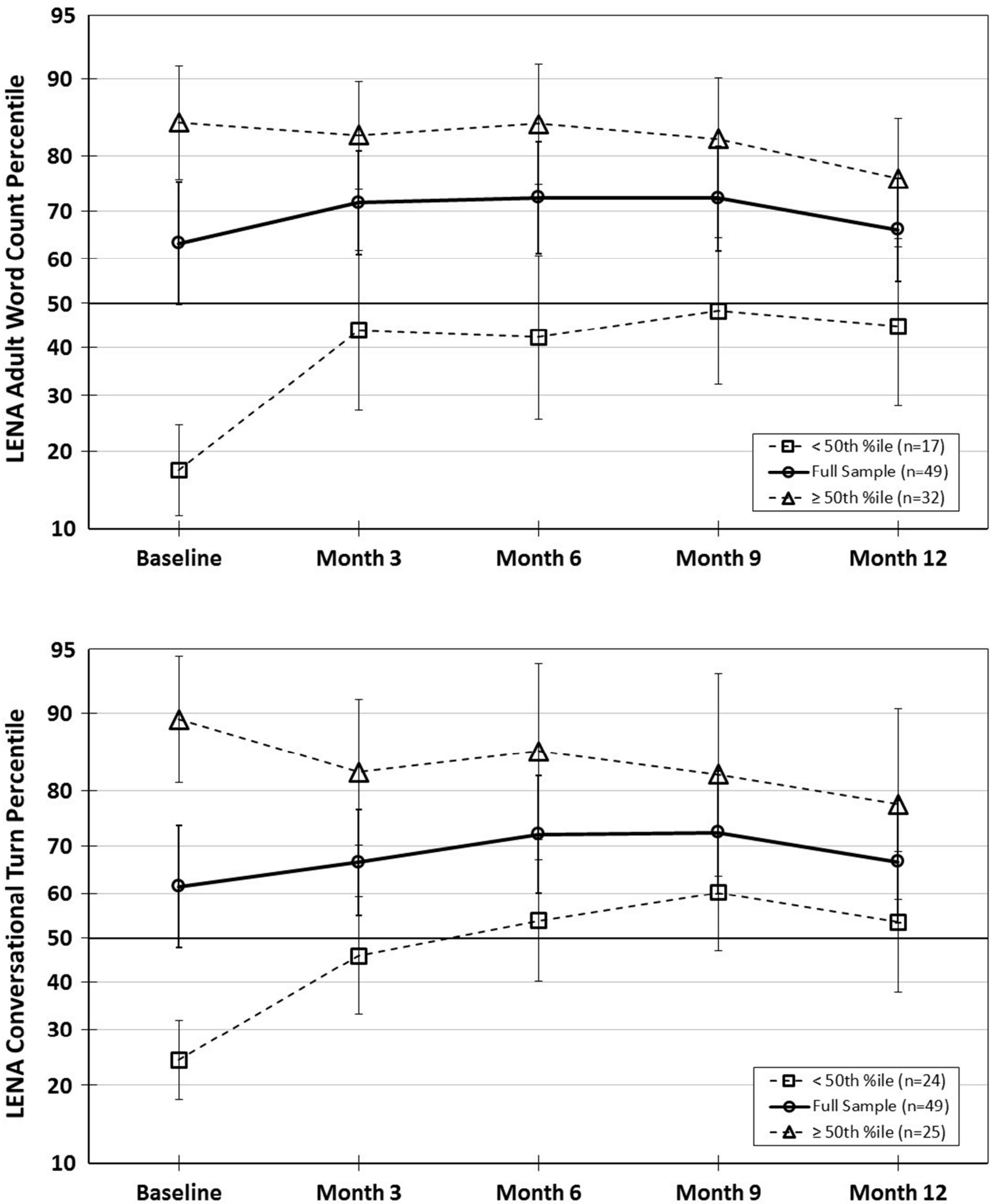

Figure 3. Change in parental language use and engagement over one year by baseline status